

Dependence of Mesoscale Coastal Predictability on Data Assimilation and Distribution of Observations

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LONG-TERM GOALS

The long term goal of this project is to determine the mesoscale atmospheric predictability and how it relates to synoptic scale uncertainty due to sampling and data assimilation of incomplete samples on the larger scale.

OBJECTIVES

The objectives of this research are to determine the ability to numerically predict mesoscale coastal structures in a variety of synoptic scale situations and demonstrate for given small scale structures the time ranges under which they might be considered predictable. The answer is probably dependent on the data assimilation system and one objective is to determine this sensitivity.

APPROACH

The basic approach is to run a series of numerical model experiments with slightly different observational samples and determine the relative spread in mesoscale forecasts. Since mesoscale truth is difficult to obtain from actual observations, we use a COAMPS model forecast as a representation of a true atmosphere. Samples are generated from this true atmosphere and then put into the data assimilation system for the MM5 model and subsequent forecasts are then verified against this truth. In this manner the impact of data sample, sample size, and data assimilation can be compared. This is being done for a variety of synoptic weather regimes to see if particular weather regimes have greater mesoscale predictability than others.

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WORK COMPLETED

A variety of numerical model experiments have been run to examine the mesoscale predictability for several weather situations. A land-falling front from the California Landfalling Jets (CALJET) experiment has been the primary focus of study with numerical experiments completed to examine the impact of synoptic-scale observational sampling and the sensitivity of mesoscale forecasts to small synoptic-scale errors. The observational sampling studies have also been done for a summer-time, Monterey Bay sea breeze situation for comparison to the more strongly forced land-falling front.

The observational sampling experiments for both the summer and winter cases have consisted of extracting random observations from a COAMPS forecast that were then subsequently blended with a NOGAPS first guess using multiquadric data assimilation. Ten different random samples of 100 soundings over the synoptic-scale domain were used to assess the synoptic-scale variance in the initial state and its impact on mesoscale error growth. These results are presented in a M.S. Thesis by Michael Kuypers at NPS.

Sensitivity experiments for the CALJET land-falling front consisted of a set of numerical experiments in which the model topography was rotated by plus/minus 1 degree. The initial conditions and model grid were identical except for the underlying topography being slightly different. These experiments simulate the error one might make by analyzing the synoptic-scale wind direction wrong by 1 degree. Experiments using various settings of cloud physics and latent heat feedback, as well as one and two-way nesting have been done. These results have been presented at numerous conferences in the past year.

RESULTS

The results of these numerical model experiments are reported in Kuypers (2000) and Nuss and Miller (2000), both of which raise some significant issues regarding the practical predictability of the mesoscale structure of the atmosphere. The study of the impact of observational sampling on mesoscale error growth has shown that errors on the 4km grid of a mesoscale model are sensitive to several factors. First, the lateral boundary conditions play a very significant role in dictating the magnitude of the error. By controlling the propagation of synoptic-scale error into the domain, the mesoscale error is very effectively limited to growth in the smaller scales only. This sets a lower bound on the total error, which is highly dominated by the synoptic-scale errors. Secondly, the growth of errors and the influence of the lateral boundaries is dependent on the weather pattern. Strong synoptic-scale forcing, such as a landfalling front, resulted in a larger growth of mesoscale error than a summertime weakly forced situation. Third, mesoscale forecasts exhibit essentially no skill when compared to the mesoscale variance of the observations. This indicates that random mesoscale noise added to a reasonable synoptic-scale forecast might be just as good as the forecast generated by a high-resolution mesoscale model. Finally, the magnitude of the synoptic-scale error does not correlate particularly well with the mesoscale error. This is presumably the result of mesoscale errors being excited by mesoscale processes that are not strongly limited by the synoptic-scale circulation. While the total error is strongly dominated by the synoptic-scale error, the mesoscale error contribution can not be easily inferred by the accuracy at the larger-scales.

The comparison of MM5 model forecasts using the slightly rotated topography show substantial sensitivity of the mesoscale wind and precipitation predictions to this perturbation of the flow. For the CALJET landfalling front, the mesoscale RMS errors in surface winds were as large as 40-60% of the

observed variability in the surface winds over the mesoscale domain and storm total precipitation accumulation errors were 20-40% of the observed variability. These errors were strongly tied to the primary terrain features but arose due to differing flow interactions with the terrain in the various simulations. The flow direction relative to the topography resulted in different frontal structures. The mesoscale errors grow rapidly (within 6 hours of model start time) and increased very substantially as the front entered the mesoscale (4 km) domain and interacted with the topography. The errors above the surface were strongly tied to the front and its differing structure between the experiments. The fact that initial synoptic-scale differences were very small (1 degree rotation of terrain) and the mesoscale error grew rapidly indicate that in some situations a nearly perfect synoptic-scale analysis and forecast may be insufficient to get the mesoscale details in the wind and precipitation correct. Although this is a single case, this model sensitivity suggests that the predictability of the mesoscale structure may be very limited for some landfalling fronts. The generality of this result to other landfalling fronts is not known and is presently under investigation.

IMPACT/APPLICATION

The impact of these studies will be in furthering our understanding of the limits to mesoscale prediction using actual numerical models and data assimilation approaches. This will greatly aid Navy forecasters in knowing how best to use forecasts from mesoscale models.

TRANSITIONS

These results have been used as classroom examples at the Naval Postgraduate School.

RELATED PROJECTS

The ONR-sponsored project by the same investigators, entitled “Evolution of Low-level Flow Patterns in Littoral Regions when Extratropical Marine Cyclones Encounter Coastal Mountains” is closely related and utilizes some of the same cases to document flow interactions with coastal mountains.